

**ALTERNATIVE PROCESSES FOR WATER RECLAMATION AND SOLID
WASTE PROCESSING IN A PHYSICAL/CHEMICAL-BIOREGENERATIVE
LIFE SUPPORT SYSTEM**

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**WORKSHOP PRESENTATION
NASA OFFICE OF AERONAUTICS & SPACE TECHNOLOGY
TECHNOLOGY FOR SPACE STATION EVOLUTION
DALLAS, TX
JANUARY 16-19, 1990**

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INTRODUCTION

During the past year, increasing attention has been focused on life support systems and the critical role they have in sustaining spaceflight crews. As these explorers undertake missions traveling greater distances from Earth and for longer periods of time, the more critical the need for regenerative life support capabilities.

The selection and development of the present candidate water reclamation technologies has been driven by the same factors requisite for most, if not all, spacecraft systems (i.e., size, weight, volume, power, etc.).

As more studies are conducted toward selection of the Water Reclamation and Management (WRM) system hardware for Initial Operation Configuration (IOC) of Space Station *Freedom*, the primary criteria (weight, volume, power, etc.) appear to have been adequately met. However, information and data found in a number of reports during the past two years indicate that secondary issues (i.e., waste composition, type and level of chemical contaminants and effects of microorganism (primarily bacterial) are significantly affecting the operation and efficiency of the

candidate systems. These issues are apparently having a greater impact on system development and evaluation than previously anticipated.

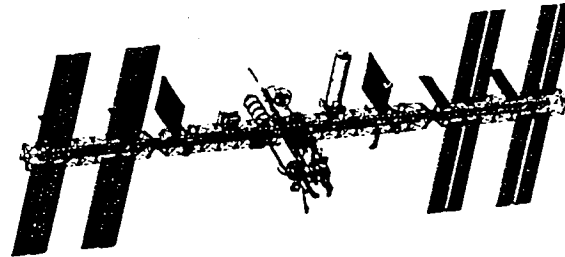
The main objective of this presentation is to focus attention on the emerging influences of these secondary factors and to constructively address these issues by discussing approaches which attack them in a more direct manner. It may be that these secondary issues will equal or surpass the primary factors in guiding the direction of evolutionary technology and design of future water reclamation and waste management/processing systems.

Using these secondary issues as a focal point, two technologies (an old one and a new, emerging technology) are briefly discussed. The technologies can be shown to have substantial merit, but more importantly it is hoped this presentation will stimulate new thinking and approaches toward reducing the impact of the secondary issues as a key element of the evolutionary system research and development. In the long run, it may turn out that these issues may be the most critical of all factors.

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SPACE STATION WATER RECLAMATION AND MANAGEMENT SYSTEM

The Space Station *Freedom* WRM system will have three systems reclaiming water for crew use. At least two of these systems will include backup units. The U.S. Laboratory will have at least two systems and backup units are included in the plans. This is a total of nine units consisting of four different system configurations. Three or four of these systems will likely have daily duty cycles, thus requiring power, monitoring of system function and water quality, consumables and intervehicular activity (IVA) crew time.



SPACE STATION WATER RECLAMATION AND MANAGEMENT SYSTEM

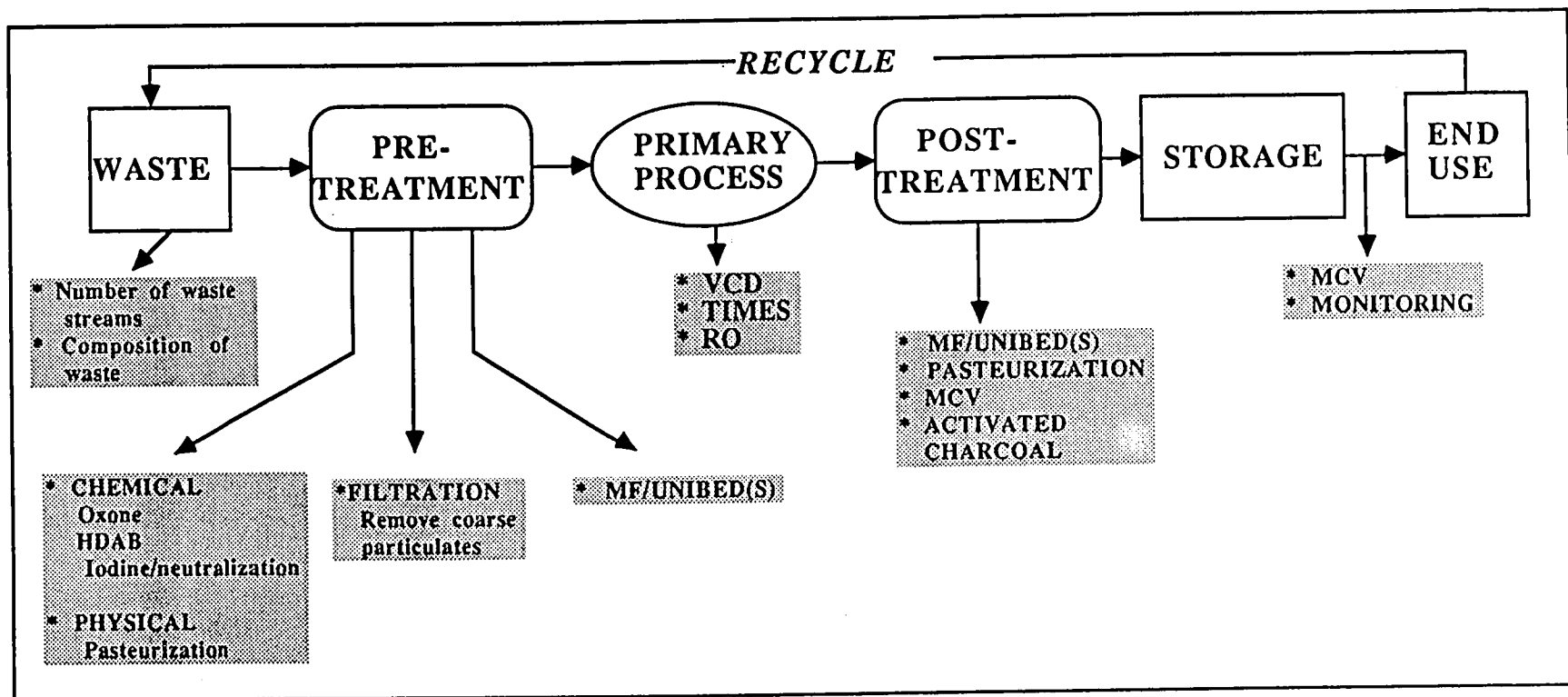
WRM SUBSYSTEM	WASTE SOURCE	WATER SPECIFICATION
1. CREW POTABLE WATER (PRIMARY) CREW POTABLE WATER (BACKUP)	* Breathing Atmosphere, Humidity Condensate * CO2 Reduction Water	Potable
2. HYGIENE WATER (PRIMARY) HYGIENE WATER (BACKUP)	* Hand/Face Washer, Body Shower * Clothes Washer * Dish Washer	Hygiene
3. URINE PROCESSOR (PRIMARY)	*Urine/Flush Wastewater	Hygiene
4. U.S. LABORATORY-Animal Experiment Facility (Water Recycle System)	* Animal Cage Washer Wastewater	Hygiene
5. U.S. LABORATORY-Ultrapure Water System (UPWS)	* Experiment Waste	Ultrapure

GENERALIZED DIAGRAM OF WATER RECLAMATION SYSTEMS

An overview diagram applicable to any of the WRM systems is shown in Figure 2. Various combinations of factors and components influence the design of each of the systems. Waste chemical composition, microorganism load and pretreatment regimen influence effectiveness of the primary process which subsequently influences the post-treatment scheme. Microorganism resistance to pretreatment or break-through of the primary reclamation process impacts the entire system and potentially necessitates primary system changeout (in the case of a Reverse Osmosis primary system) or implementation of cleanup procedures of the hardware (VCD or TIMES).

Looking at this situation from another perspective, assume: (1) two or more of the present waste streams could be combined, (2) chemical composition could be more complex, yet less compromising, and (3) the microorganism load and influence is of no concern on the input side with control of microorganisms being the prevention of back-contamination at enduse points. Such an approach would reduce the number of major systems required for primary water reclamation with more attention being focused on post-treatment assemblies to provide the required water quality. Such a step directly addresses effectiveness and efficiency of the entire WRM.

GENERALIZED DIAGRAM OF WATER RECLAMATION SYSTEMS



WATER RECLAMATION USING EVAPORATION, CATALYTIC OXIDATION AND CONDENSATION

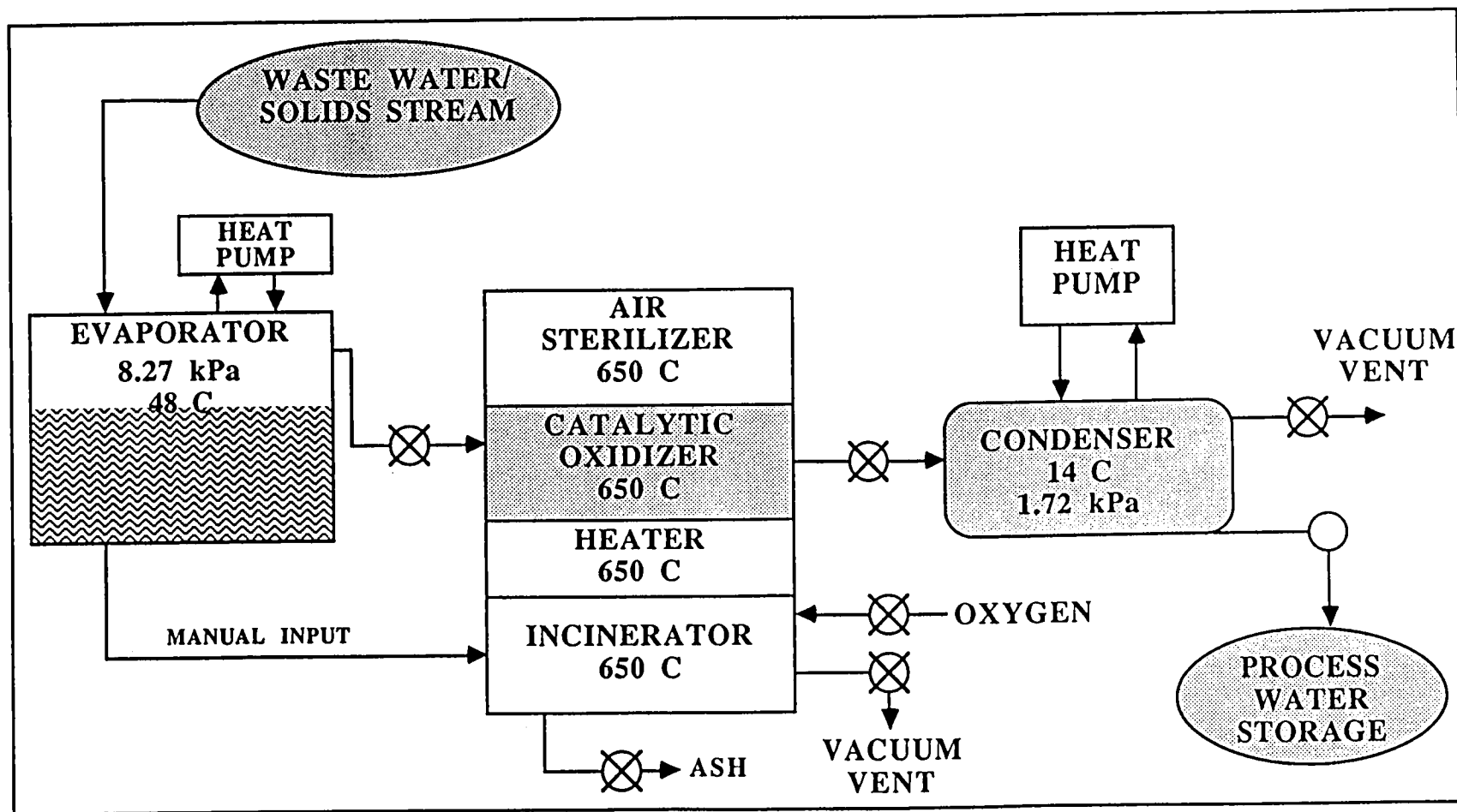
Using an evaporation, catalytic oxidation and condensation process (referred to earlier as an "old" technology) chemical wastes containing substances known to compromise the present candidate systems, were prepared and processed as shown in Figure 3. The objective was to assess the capability of this process to reduce the total organic carbon (TOC) content to a reasonable level using single-pass treatment. This objective was achieved and the hardware/components were not compromised by the waste stream chemicals.

No attempt was made to investigate the microorganism influence because this aspect was more than adequately investigated and reported by General Electric in

studies conducted in the early 1970's. Extensive, periodical microbial monitoring of reclaimed water was conducted during a simulation test lasting more than 180 days. Microorganism presence was not detected in any of the sampling tests as a result of process breakthrough, no did microorganisms have any impact on the process from the influent stream side.

It is pointed out that a variety of pretreatment measures have been employed to reduce the presence and effects of microorganisms of influent waste streams relative to the current technologies, yet little or no attention has been accorded the results of the above studies from nearly two decades ago.

WATER RECLAMATION USING EVAPORATION-CATALYTIC OXIDATION-CONDENSATION



**PHASE CHANGE - CATALYTIC OXIDATION -
CONDENSATION PROCESSING OF CHEMICAL
WASTE WITH HIGH TOTAL ORGANIC
CARBON (TOC) CONTENT**

Chemical wastes shown in Figure 4 were prepared and processed in the hardware system outlined in Figure 3. The main point of emphasis in the results is that waste having a high TOC was reduced by single-pass processing to a level within, or approaching the TOC specification for hygiene water (10 ppm).

The sodium lauryl sulfate/sodium hydroxide test

solution was processed because such chemicals represent an appropriate detergent for use in animal cage washing and a suitable chemical (sodium hydroxide) for removal of biofilm. Single-pass reclaimed water within the specifications for hygiene quality water is a feasible starting point for posttreatment processing to produce both potable and ultrapure water.

PHASE CHANGE - CATALYTIC OXIDATION - CONDENSATION PROCESSING OF CHEMICAL WASTE WITH HIGH TOTAL ORGANIC CARBON (TOC) CONTENT

CHEMICAL WASTE	PRE- AND POST TREATMENT ANALYSES*					
	SPECIFIC CONDUCTANCE		TOC(mg/l)		AMMONIA NITROGEN(mg/l)	
	PRE-	POST-	PRE-	POST-	PRE-	POST-
Acetic Acid 10 ml/L 2-Propanol 10 ml/L Ammonia Hydroxide 10 ml/L	8890	34	4010	7.5	1050	1.33
Lactic Acid 10 ml/L Methanol 10 ml/L Urea 2 gm/L	1620	123	5632	12	34.2	0.91
Sodium Lauryl Sulfate 10 gm/L Sodium Hydroxide 20 gm/L	70010	143	640	10	1.98	0.06

* Analyses performed by Inter-Mountain Laboratories,
College Station, TX.

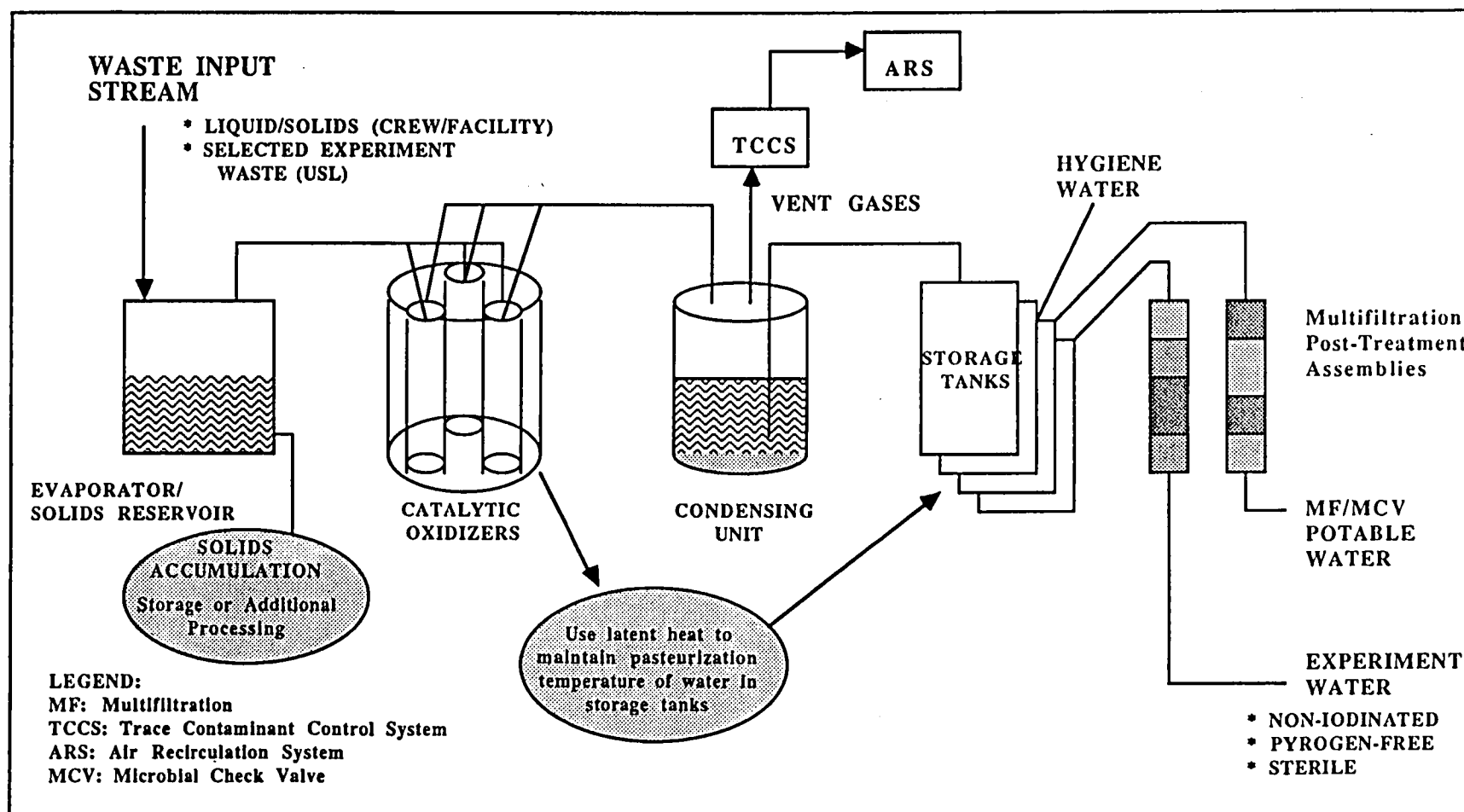
MINIMIZING EFFECTS OF MICRO-ORGANISMS AND CHEMICAL CONTAMINANTS IN A WATER RECLAMATION SYSTEM

If a single, front-end approach to waste stream treatment is assumed, and effects of chemical composition and microbial load are minimized or negated, the main focus of the reclamation process then centers on the post-treatment assemblies to provide the appropriate type of end-product water.

Another aspect this process addresses is that of solids/particulates. The influent reservoir (also the evaporator) accumulates solids which can be removed without expending consumables (i.e., filters). Furthermore, there is a potential to concentrate the solids by using latent heat of the oxidation process to dry this material to minimize requirements for mass and volume storage and return logistics. A high percentage of solid waste water content or moisture can be recovered and maintained within the recycle loop.

Through application of advances in engineering technology, materials, instrumentation and catalysts at lower temperature regimens, the energy requirements for operating this 18-year old hardware system can be significantly reduced. At least half of the issues listed in the following table are already known to be substantially resolved by using phase-change - catalytic oxidation - condensation to recover water and concentrate solids of a complex waste stream.

MINIMIZING EFFECTS OF MICROORGANISM AND CHEMICAL CONTAMINANTS IN A WATER RECLAMATION SYSTEM

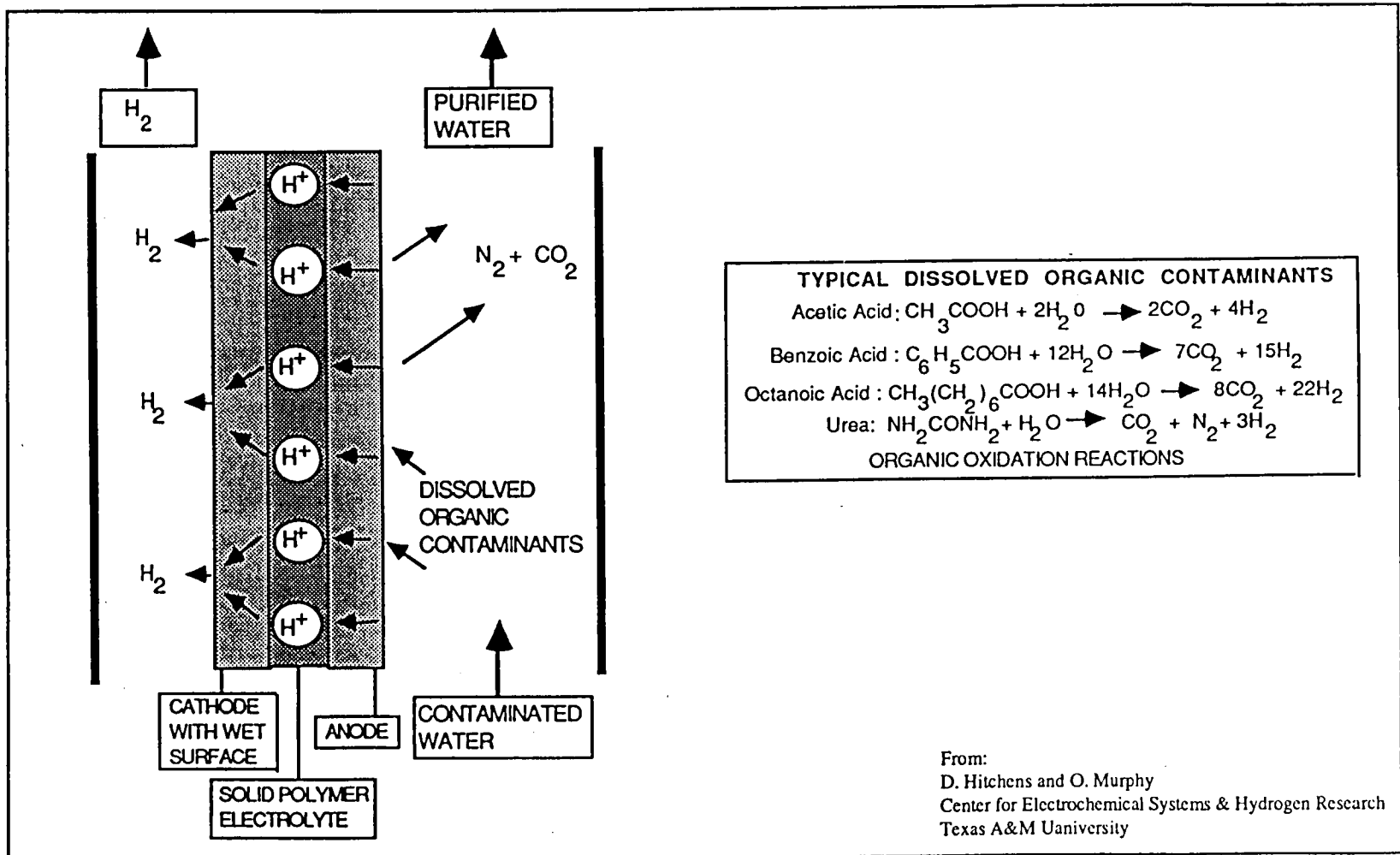


ELECTROCHEMICAL UNIT FOR WATER POST TREATMENT

This process represents a means of treating recovered waste water without the use of chemical expendables and currently is being investigated as a pre and post treatment method. The design is based around the use of a solid polymer electrolyte (SPE) similar to that used in fuel cells. Organic contaminants are removed by oxidation as water is passed over the anode surface.

In feasibility studies, the level of contamination of water containing typical organic contaminants of space craft recovered water was reduced from 50 ppm to 1 ppm and below. Another aspect of this process is that, by utilizing suitable electrolytes, SPE-based electrolysis systems can generate short-lived oxidizing species in the recovered water providing unique post treatment and disinfection capabilities.

ELECTROCHEMICAL UNIT FOR WATER POST TREATMENT

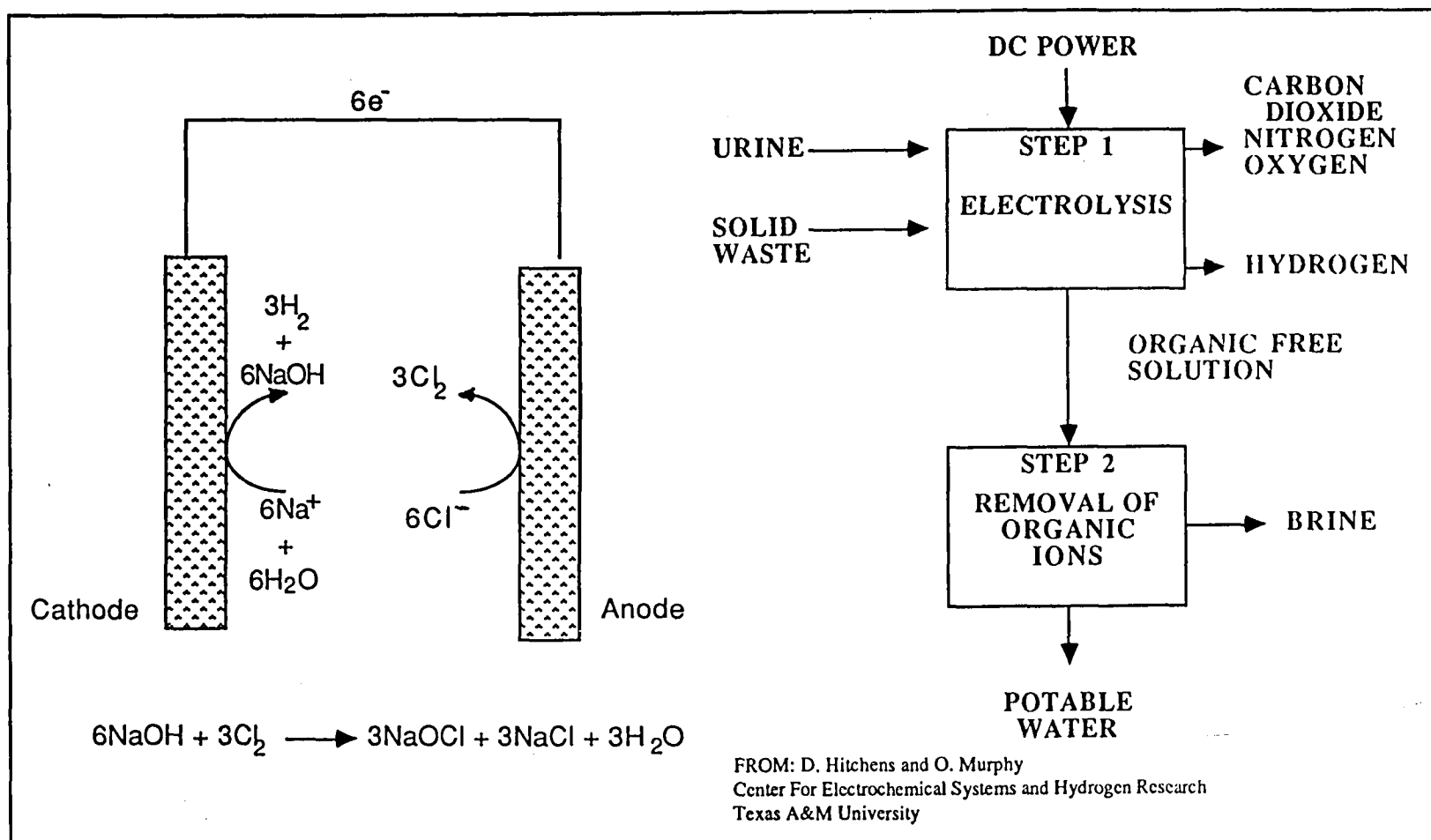


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ELECTROCHEMICAL SOLID WASTE PROCESS- ING AND WATER RECOVERY

Urine contains high levels of chloride ions. Electrolysis of these wastes produces chlorine at the anode which leads to the buildup of hypochlorite in the waste. Hypochlorite is a powerful disinfectant and particulate solids are dissolved during this treatment. In addition, the treated material is partially purified through the oxidative removal of dissolved organic material. This represents a means of pre-treating urine and solid waste, for recovery of water, without the use of expendables.

ELECTROCHEMICAL SOLID WASTE PROCESSING AND WATER RECOVERY



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ISSUES INFLUENCING EVOLUTIONARY TECHNOLOGY DEVELOPMENT

No reports have been found assessing the impact the factors previously listed (Fig. 6) would have on IOC Space Station *Freedom* once the selected systems are placed in operation. However, it is understood that since actual system selection and final design are not yet established and extensively tested, the full compliment of factors can not be accurately evaluated.

In the past, studies have been conducted to assess the attributes of a primary reclamation process or a trade study performed where several systems were compared to arrive at cost and efficiency estimates for a 10-year life expectancy, at least half of the above factors were not adequately considered or not considered at all.

ISSUES INFLUENCING EVOLUTIONARY TECHNOLOGY DEVELOPMENT

OBJECTIVE:

WRM Technology Development Must Focus On Reducing The Need For:

- * Waste pretreatment procedures**
- * Number of in-line components or treatment subsystems**
- * Consumables**
- * Process residuals (brines/rejection concentrates)**
- * Monitoring requirements**
- * Storage requirements**
- * Resupply and return logistics**
- * IVA monitoring, maintenance and repair time**

PLANNING FOR EVOLUTIONARY TECHNOLOGY DEVELOPMENT

Figure 7 revisits several excerpts illustrating planned objectives for evolutionary technology direction. The task at hand is to closely assess factors and issues discussed in this report (including issues not mentioned) and use the conclusions to organize and implement the appropriate research, development and testing program.

The primary factors (i.e., size, weight, volume,

power, etc.) which have influenced the present systems may not be as critical in the future. For example, advances in space power generation, storage and delivery will lessen the impact of this factor. Development of a Lunar Outpost moderates the concern for weight and size, and artificial gravity or lunar gravity negates certain issues relative to microgravity.

PLANNING FOR EVOLUTIONARY TECHNOLOGY DEVELOPMENT

PLANNING FOR TECHNOLOGY EVOLUTION:

"Water Reclamation: Direct treatment of waste water (urine, wash water, and condensates) by processes not using any expendables to provide potable and hygiene water by reclaiming high content of waste waters by...:"

- * "Direct removal of the total water content."
- * "Direct removal of the undesirable chemical impurities (organics/inorganics)."
- * "Phase-change treatment systems utilizing lunar/Martian gravity or microgravity."
- * "Handling and treatment of processed water (post treatment) to remove trace contaminants and bacteria without expendables."

From: Small Business Innovation Research, Section 12.03, Regenerative Life Support: Air, Water and Waste Management. SBIR 89-1, p 81, 1989.

CURRENT STATUS:

The phase-change(evaporation), catalytic oxidation, condensation process discussed in this presentation already meets most, if not all, of these requirements.

The electrochemical system discussed in this presentation is a prime candidate to meet these requirements.

UV-Ozone treatment is also a prime candidate.